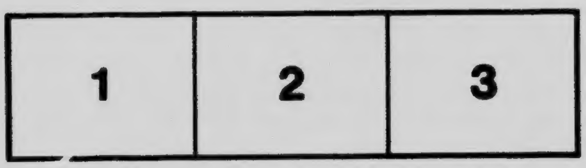
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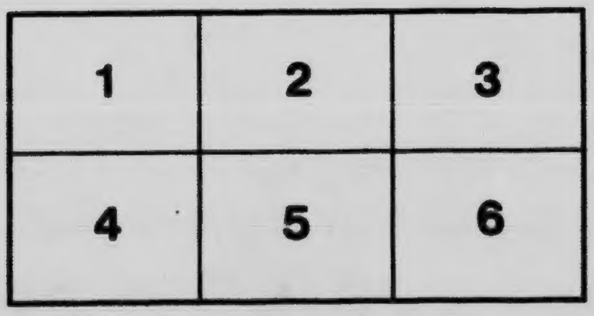
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A FIRST COURSE IN CHEMISTRY

PART I.

BRITTAIN

Weighing Material for Experiments.

A FIRST COURSE IN CHEMISTRY

FOR THE USE OF STUDENTS
AT HIGH SCHOOLS AND NORMAL SCHOOLS
AND FOR BEGINNERS' CLASSES
IN GENERAL

BY

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PREFACE

THIS book has been written for the use of students taking their first course in chemistry at a High School or Normal School. It deals mainly with the chemical properties and relations of substances which are in common use, and with the interpretation of chemical phenomena which come within the range of ordinary experience. It is the result of an endeavour to render chemical knowledge of greater service in the daily life of the people.

Chemical science is often introduced to the beginner in such technical form and so overloaded with theory, that the struggling student is perforce compelled to treat the subject as something to be received on authority and committed to memory, in the vague hope that it may become intelligible to his matured mind, and at some future time throw a little light on his pathway; or, at least, enable him to pass an approaching examination.

The experiments in this course require only the simplest and cheapest apparatus. One advantage of this is that the attention of the student can be more easily concentrated on the substances and reactions he is studying, and another is that it will enable many schools, which have hitherto been deterred by the expense, to provide and maintain, at a trifling cost, a laboratory course in elementary chemistry.

It will be noted that each student is expected to observe all chemical changes which occur in the experiments, to offer an explanation of them in his notes, and to support his conclusions by careful arguments in which all the known facts which bear upon his interpretations are marshalled in logical order. This constant appeal to the reason will make the subject more interesting to the thoughtful student, and will gently compel those who are inclined to be indolent or superficial to become more thoughtful.

The study of the chemical composition and properties of vegetable products fills a considerable place in these lessons, for the reason that these organic substances are so closely connected with human life and its interests.

While this feature is intended for the benefit of the many, it will not make the book less useful to the few as an introduction to further studies in chemical science.

CONTENTS

PART I

DIRECTIONS FOR LABORATORY WORK

1. Work quietly, that is, talk as little as possible, and that in a low tone.

2. Always read the directions through carefully before beginning an experiment; then, if you do not remember the process throughout, go through all the manipulations without using the chemicals, to prepare yourself for performing the real experiment successfully and promptly.

3. Before beginning an experiment get ready all the apparatus necessary to complete it.

4. Notice closely all changes which occur in the substances with which you are experimenting. If bubbles arise, find what gas is being set free; if a new smell or colour is observed, find what substance having this colour or smell has appeared; if a precipitate forms in the liquid, show what the composition of this precipitate should be, and its name. In general, if any substance is disappearing, find why it disappears and what is becoming of it, and if any new substance appears, find why it appears, whence it came, and of what elements it is composed.

5. Think out, as you proceed, the interpretation of each change you observe, and spend any spare time you have between experiments or while awaiting their completion, in writing notes.

6. When you have completed your experiments, wash and wipe all apparatus which needs cleaning, and arrange it in its proper place.

7. Do not empty out any residues wi[illegible]n be used again. Empty solid wastes into a suitable receiver and liquid wastes into a sink.

8. When you have thus finished your work at the table, take your place in class and complete and correct your notes.

CAUTION.—Guard against accidents, especially from fire, acids, and alkalies. One's clothing may be set on fire by spilling alcohol from a lamp in use, or by a gas flame. Water should always be kept at hand for use in such an emergency. The fire may be checked by wrapping the person closely in a woollen garment to exclude the air.

The effect of an acid on the skin or clothing may be neutralized by promptly applying an alkali (preferably ammonia) and *vice versa.*

FIRST COURSE IN CHEMISTRY

PART I—FIRST TERM

CHAPTER I

The Granular (Molecular) Structure of Matter

Experiment 1. Fill a test tube or flask with coloured water, and insert a cork through which passes a piece of small glass tubing about one foot long, open at both ends. Allow the coloured water to rise part way up the small tube, as you force the cork into the mouth of the test tube or flask. Heat with a lamp flame, without boiling, the coloured water, and note the effect upon the volume of the water. Allow the water to cool, and observe the visible result.

Experiment 2. Prepare a flask or a large test tube, as in the preceding experiment, and leave the whole apparatus full of air. Invert the apparatus over a jar containing coloured water and let the mouth of the tube dip an inch or more into the water. Heat the test tube or flask till part of the air in it has been expelled; then let it cool, but do not allow the water to rise far enough to crack the hot glass.

Experiment 3. (Optional.) Heat a ball of metal, which will just pass through a metallic ring, until it expands so much that it will not pass through the ring. Cool the ball in water and then try whether its volume has changed in the cooling.

Experiment 4. Take five shallow dishes, one containing a little water, three containing a solution in water of sugar, of salt, and of blue vitriol, respectively, and one a mixed solution of common salt and blue vitriol, the liquid in each being about one-third or one-half an inch deep. Set the dishes in a warm place until the water disappears from the first, and the contents of the others become dry. The temperature should be such that the evaporation will require a day or two at least. Examine and compare the residues.

Experiment 5. Stir a small pinch of powdered dye into a large glass vessel full of water.

(*a*) Briefly record the results of each of these experiments, and point out which of the observed facts require explanation, and why.

(*b*) Assume that solids, liquids, and gases are granular in structure, that is, composed of separate grains, these grains being so small that we cannot see either them or their movements, and explain by means of this supposition or theory *how* (not *why*) the observed results of the preceding experiments were brought about.

(*c*) Try to think of any other theory which will explain these facts as satisfactorily.

(*d*) Give then your reasons for *believing* (not for *knowing*) that all bodies, solid, liquid, and gaseous, are composed of minute grains too small to be seen even with the aid of a microscope.

DEF. These minute grains which we suppose to move further apart, or draw more closely together, in the preceding experiments, are called **molecules**, and the belief in them is called the **molecular theory**.

DEF. The regular forms into which the molecules of a substance often group themselves when the substance is passing from the liquid into the solid state, are called **crystals**.

(*e*) Compare a crystal of common salt with a crystal of blue vitriol, and consider whether the molecular theory can throw any light on the formation of these crystals, or help to account for their differences.

DEF. The force by which the molecules of a body are bound together to form visible masses, is called **cohesion**. The molecules of solids and liquids are said to *cohere*. When the force of cohesion acts between the molecules of *different* substances, it is called **adhesion**.

*** It must be made clear that we believe in the granular structure of solids, liquids, and gases simply because the theory that matter of all kinds and forms is made up of molecules (minute particles) enables us to explain expansion and

contraction through change of temperature, evaporation, solution, crystallization, the diffusion of a dye through a liquid, and many other phenomena, better than any other theory yet proposed, and has never failed to explain any fact coming within its sphere. We believe in the theory, not because we can see, or expect to see, the molecules of which air, water, gold, and the other kinds of matter are made up, but because of the *explaining* power of the theory. When we remember that there are some plants and animals so small that they cannot be seen by the naked eye, and only become perceptible through the aid of a microscope which magnifies several hundred diameters, it will appear quite reasonable that there may be particles of matter too small to be seen even with a microscope.

CHAPTER II

A Lesson on Heat

Experiment 1. Heat a piece of metal by holding it in a flame. Try whether you can heat another piece of metal by pounding it with a cool hammer upon a cool anvil or stone.

(*a*) Show by means of the molecular theory how the result was produced in both cases, and why the results were similar.

(*b*) Explain how it happened that the metal became hot without applying heat (or anything hot) to it.

Experiment 2. Try whether you can heat perceptibly two dry sticks by rubbing them together.

(*c*) Explain by the molecular theory the ancient method of kindling a fire by rubbing two dry sticks together.

Experiment 3. Repeat Experiment 2, Chapter I, and after the water has risen into the neck of the flask or test tube, heat the air above the water, until part of the latter is pressed back out of the tube.

(*d*) Explain how the heat increased the pressure of the air upon the water.

(*e*) State your reasons for believing that the heat of a body is due to the motion (vibration) of its molecules.

(*f*) Explain why it is correct to speak of a *hot body*, but quite inaccurate to speak of a *hot molecule.*

(*g*) Account for the injury caused to your finger by touching red-hot iron.

(*h*) Argue that there are spaces between the molecules of bodies (intermolecular spaces).

⁂ It appears from experiments 1 and 2 that in order to make a cold body warm or hot, it is only necessary to perform some operation upon it which will be sure to set its minute particles (molecules) in more rapid motion. The motion of the molecules, which causes the sensation of heat, must be a backward and forward one, that is, a vibration, while the molecules remain within the limits of the body, and even after their escape, for they then become parts of another body, within whose limits they remain, although in motion, often for a very long time. The ability of a flame to communicate heat is evidently because the molecules in the flame are vibrating with great rapidity.

CHAPTER III

Chemical Union and Chemical Separation

The Atomic Theory

Experiment 1. Heat slowly, with as little smoke as possible, in a test tube closed with the thumb, a little *dry wood*, until a clear liquid becomes visible in small drops in the cooler part of the tube. Take out some of this liquid on a glass stirring rod, and by its obvious properties determine what it is.

Experiment 2. Raise the thumb, and heat the test tube again. Taste the dark liquid which appears, and smell the vapours which escape from the open tube. Continue to heat the tube until the residue is dry. Knock out part of the black solid which remains, fasten it in a wire catch or holder, and try whether it will burn in the flame.

Experiment 3. When the test tube has cooled, fill it with water and note whether the black solid dissolves in the water as sugar would.

(*a*) Show by the above experiments what two common substances dry wood contains, and state the properties by which you identified the two.

(*b*) What facts did you observe which seem to indicate that wood contains other substances than these two? Chemists have found, however, that pure wood contains only charcoal (carbon) and (the elements of) water. The tastes and smells perceived in experiment 2 we shall try to explain in a future chapter.

(*c*) Explain why neither the charcoal, nor the water which we got out of the wood could be seen, felt, or otherwise perceived before we heated the wood.

DEF. When two substances are united in such a way that they conceal one another's properties, and together form a substance quite different in its properties from either of them, the two substances are said to be *chemically united*, or in *chemical union*.

(*d*) By what means did you bring about the *chemical separation* of the two substances which are chemically united in wood?

DEF. A substance which is not chemically united with any other is said to be *free*. Point out how to set free the charcoal which in wood is *combined* with water.

Experiment 4. Heat a piece of hard, *dry* charcoal in a dry closed test tube in an attempt to separate charcoal into two different substances as you did wood by the same means. Note the only perceptible effect.

DEF. Neither by this nor any other means have chemists been able to break up charcoal (carbon) into two different substances. For this reason carbon is called a **simple substance**, or *chemical element*, while wood is called a **compound substance**, or *chemical compound*.

(*e*) Argue that the smallest particles of wood (the molecules), although each of them is a little piece of wood, are not made up of wood, but of carbon and water.

(*f*) Point out then that there must be smaller particles than molecules.

DEF. The smallest particle (a unit mass) of a simple substance which may enter into chemical union with other particles to make up a molecule, is called an **atom**. The force which binds atoms together to form a molecule is called **chemical affinity**.

⁂ Since carbon is a simple substance, it is plain that a molecule of carbon is entirely composed of atoms of carbon. It also appears that the smallest particle of wood is not an atom but a molecule, for the molecule of wood consists not of atoms of wood, but is made up of carbon and water. Though carbon is a simple substance, we may find that water is a compound substance.

It was supposed for a time that atoms were the smallest (lightest) particles of matter, and that they were incapable of being divided into parts. It is now believed, however, that atoms contain still more minute particles called *electrons*. It will not be necessary for us to consider or make use of the electron theory in this course.

CHAPTER IV

PREPARATION OF OXYGEN AND OF CARBONIC ACID GA

Lime-water for this and following lessons should be pre pared in advance. Put two or three inches of fresh water slacked lime into a tall bottle (or jar), and fill the bottle u with water. A little of the water-slacked lime will dissolve The clear solution is called lime-water. The supply may b maintained by adding fresh water to the water-slacked lim which remains at the bottom. Keep the bottle corked.

Before beginning these experiments prepare a piece of sof charcoal for experiment 3 by twisting the end of a brass wir around it so closely that the charcoal cannot fall out, even i it should become considerably smaller. The charcoal may b obtained by charring a piece of wood. Wide-mouth pre scription bottles, 4 oz. to 8 oz. size, and one-half pint mill bottles, will suit well for collecting gases. An ordinary enamelled metal basin three or four inches deep may be used for a pneumatic trough.

Experiment 1. (*a*) Put half a teaspoonful of chlorate of potash, and about one-fifth that bulk of black oxide of manganese into a test tube, and mix them by shaking the tube. Then insert a cork with a delivery tube, suitably bent.

(*b*) Invert two bottles of water (one larger than the other) in a basin containing water at least two inches deep.

(*c*) Heat the mixture in the test tube till a glowing test stick (splinter of wood or wooden toothpick) will take fire when held at the mouth of the delivery

LEFT: BURNING OXYGEN IN HYDROGEN, CHAP. VI. RIGHT: PREPARING OXYGEN, CHAP. IV.

tube, and then fill by downward displacement of water the two inverted bottles with the gas which is set free.

Experiment 2. Cover, under water, the mouth of the smaller bottle with a slip of glass; turn this bottle mouth up, quickly shake a little clear lime-water through the gas, and note the effect.

N.B.—In experimenting with a gas, never leave the mouth of the bottle or other container uncovered for more than an instant lest the gas escape or mix with the air.

Experiment 3. Cover the mouth of the larger bottle and turn it up. Heat a piece of soft charcoal in the flame till part of it is *glowing* without a flame, and then plunge, held by the wire, the charcoal half way down or more into the bottle. Note whether the charcoal gets hotter or colder. When it has nearly ceased to glow, take the charcoal out, quickly cover the mouth of the bottle with a wet slip of glass, shake a little clear lime-water through the bottle, and note the result. Also note the effect on the size and appearance of the charcoal.

(*a*) The gas which was set free in experiment 1 is called **oxygen**. Tell why oxygen is regarded as a simple substance or chemical element.

(*b*) Show that part of the charcoal disappeared in the bottle, and what became of it.

(*c*) Argue out the composition of the new gas which you found in the bottle after the charcoal was burned there, and name it carbonic acid gas. Tell how to distinguish this gas from oxygen.

(*d*) Explain why the carbon got so much hott when it was put into the bottle of cool oxyge Point out how the heat was produced and why is called **heat of chemical union.**

(*e*) Account for the grayish powder which a peared on the charcoal where it had been burnin That part of the charcoal disappeared (burned awa in the bottle of oxygen may be shown by balancin the charcoal and wire on a scale, before the burnin and again afterward. The charcoal which disa peared in the bottle, if it were still free, could l seen there in the solid state as soon as the bott cooled. We must conclude that the lost carbo disappeared by uniting chemically with the oxyge in the bottle; the new gas (carbonic acid gas) whic turned the lime-water milky must be a compour substance composed of carbon and oxygen.

⁂ This gas is a good illustration of the fact that wh two substances unite chemically they form a new substan quite different from either of the two which united. Th result of chemical union is quite surprising, for one wou naturally expect that the new substance would bear a evident resemblance to one or both of the two from whic it is formed.

In accounting for the intense heat which lasted as long a the chemical union was going on, we must picture out th atoms of carbon and atoms of oxygen rushing together t form molecules of the new gas. It is plain that when th atoms come together, the new molecules thus formed take the motion lost by the atoms which formed them, and quently the molecules of carbonic acid gas vibrate ry rapidl when first formed, and striking against the outside of th piece of charcoal cause the charcoal molecules to vibrat rapidly also, and so the piece of charcoal becomes so hot tha it glows far more brightly.

CHAPTER V

THE PREPARATION AND PROPERTIES OF HYDROGEN

Experiment 1. Cover about an inch of commercial granulated zinc or zinc cuttings in a test tube with water, and note the result. (Zinc is a simple substance.)

Experiment 2. Empty the water off the zinc, and cover the zinc with *dilute* hydrochloric acid. Test, with a glowing and with a blazing test stick, the gas which issues from the test tube. (If the gas is not set free quickly enough, the action may be hastened by adding a little powdered blue vitriol.)

(*a*) Tell how to distinguish this gas from oxygen, and why it is called a chemical element. Its name is **hydrogen.**

(*b*) Show which of the three substances in the test tube the hydrogen came out of.

Experiment 3. Empty the liquid off the zinc into a tumbler or sink; cover the zinc with dilute acid again, quickly insert a delivery tube, collect by displacement of air a *small* bottleful of hydrogen by holding the mouth of the delivery tube in the mouth of the inverted bottle, and set fire to the hydrogen you thus catch in the *wide-mouth* bottle.

Experiment 4. Pour the liquid off the zinc,

cover the zinc with acid, insert the delivery tube, se fire to the gas as it issues from the delivery tube, an hold a clean, cool tumbler inverted above the flam so that the flame is close *below the mouth* of th tumbler. Identify by touch and taste the liqui which collects on the inside of the tumbler. Ther try whether you can collect any *hydrogen* by holdin a small bottle inverted over the hydrogen flame.

(*c*) Explain as far as you can the results of th last experiment.

(*d*) Why could you not see at first the liquid which you collected in the tumbler above th hydrogen flame?

Experiment 5. Collect over water in a basin or pneumatic trough a wide-mouth 6 oz. bottle full of hydrogen. Raise by one hand the bottle of hydrogen, mouth down, up into the air, and with the ther hand plunge a burning taper or candle up nto the bottle of hydrogen. Lower the candle steadily until it is out of the bottle, and then push it up again several times, to find how often you can extinguish and relight the flame.

(*e*) Show why the flame was rekindled when the candle was descending out of the bottle, and why it was extinguished when pushed up into the bottle. What properties of hydrogen were illustrated by these experiments?

*** Rinse the zinc remaining in the test tube by shaking water through the tube. Pour off the water, and leave the remaining zinc in the tube to be used later in the preparation of hydrogen.

CHAPTER VI

Burning Oxygen in Hydrogen. Composition of Water

Experiment 1. Collect over water in a basin or pneumatic trough, a wide-mouth bottle (about 8 oz. or ½ pt.) full of hydrogen, and let the bottle remain with its mouth in water so that the hydrogen cannot escape.

Experiment 2. Mix in a test tube half an inch (depth) of chlorate of potash and a *little* black oxide of manganese. Insert a bent delivery tube into the mouth of the test tube, and heat the mixture until the oxygen set free by the heat will set ablaze a test stick with a glowing (red-hot) tip held at the mouth of the delivery tube. Try whether the blazing stick will set the oxygen afire, that is, whether the oxygen burns at the mouth of the tube after the burning stick is removed.

Experiment 3. Hold the test tube so that the mouth of the delivery tube will be turned nearly *vertically upward.* Keep the bottom of the test tube in the flame of the lamp or burner all the while, *so that the oxygen will continue to flow steadily from the mouth of the delivery tube.* Raise the bottle

of hydrogen up, with its mouth still downwar *Set fire to the hydrogen* with the flame of a lam or a match held at the mouth of the bottl and then lower the bottle down over the ope end of the delivery tube until the delivery tul reaches half way to the bottom of the bottl The escaping oxygen should take fire as th delivery tube enters the bottle, and burn bright in the hydrogen. As soon as the burning cease remove the delivery tube from the bottle, and once cover the bottle's mouth with the hand a slip of glass.

Experiment 4. Promptly test the contents the bottle with a glowing and with a blazing te stick, to find whether the bottle yet contains th hydrogen or the oxygen which were passed int it, and identify by touch and taste the liquid whic dampens the inside of the bottle.

(*a*) Account for the disappearance of the hydro gen in the bottle while the oxygen was burnin in it.

(*b*) How do you explain the fact that the onl substance we can collect rising from a hydroge flame is *water*, and why this is the *only* substanc which makes its appearance when oxygen burns i hydrogen?

(*c*) Show, then, as conclusively as you can, tha water is a compound substance, and what it elements are.

(*d*) How is it that water is produced when hydrogen burns *in the air*, as well as when oxygen burns in hydrogen? See Chap. V, Expt. 4.

(*e*) Why would the oxygen not burn in the air, as it issued from the delivery tube?

(*f*) Show whether the heat of the hydrogen flame is heat of chemical union.

CHAPTER VII

Some Instructive Experiments

Experiment 1. Make in a test tube a mixtu
about three-quarters of an inch deep of chlorate
potash and black oxide of manganese, in the sa
proportion as in other experiments, and balance t
whole (test tube and mixture) on a scale. Sa
may be used in making the balance exact.

Experiment 2. Heat the mixture, collect the ox
gen set free, over water, in bottles, and use th
oxygen for experiments which suggest themselv
as suitable for illustrating the properties of oxyge
When the oxygen begins to flow slowly and wi
difficulty from the heated mixture, remove t
delivery tube in order that the pressure of air up
the water may not force it back into the hot te
tube, and heat the mixture until a glowing test sti
will not burst into flame when held in the mou
of the test tube.

Experiment 3. Place the test tube and its co
tents on the scale again; find whether there h
been a gain or loss in weight, and how much.

(*a*) Account for the difference in weight, and poi
out what this difference is apparently the weight o

Experiment 4. Add a pinch of black oxide of manganese to the contents of the test tube. Apply heat again, and find by a test stick whether oxygen is set free. Then add a little chlorate of potash, heat, and test again.

(*b*) Interpret the results.

Experiment 5. Collect over water two small wide-mouth bottles full of hydrogen. Raise one of them up, mouth down, and after waiting a minute, set fire to the gas in it with the flame of a match or test stick. Lift the other bottle, turn it mouth up, and after waiting as before, try to set fire to its contents in the same way. Collect the same two bottles full of oxygen, and try similar experiments with it, using a *glowing* test stick instead of a flame.

(*c*) Interpret the results, and point out why black oxide of manganese is used in preparing oxygen.

Experiment 6. Add enough (¼ inch deep) chlorate of potash to the contents of the test tube used in experiments 1 to 4, and collect over water, in a thick bottle of about 6 oz. capacity (a soda water bottle for example) one-third of the bottle full of oxygen. Then fill the remaining two-thirds of the bottle with hydrogen.

Experiment 7. In two or three minutes wrap the bottle, except at the mouth, with a damp towel, for safety, cover the mouth of the bottle under water

with the hand or a slip of glass, raise the bottle ou of the water, uncover its mouth and ignite th mixture with a flame held in the mouth of th bottle, holding the bottle mouth down *all the tim*

Experiment 8. Repeat experiment 7, using different proportion of the two gases (say on volume of hydrogen to two of oxygen), and observ whether you get a louder or weaker explosion.

(*d*) Point out what became of the hydrogen an oxygen which took part in the explosion. Explai the cause of the explosion, and why you got louder noise in one case than in the other.

⁂ In explaining the explosions in experiments 7 and 8 it is necessary to point out that we begin with a mixture o hydrogen and oxygen (which is not water), and that whe the flame is applied the two gases unite chemically to forn water. The intense heat produced by the sudden chemica union would expand the water (steam) formed by this unio instantaneously, and thus cause a violent outrush of stean from the bottle, followed by a sudden inrush of air. Th sound waves thus produced in the air impress the ear as a explosion.

The last two experiments indicate that the hydrogen an oxygen unite to form water in the proportion of two volume of hydrogen to one volume of oxygen, for it was this propor tion that gave the greater heat—hence the greater expansio —hence the louder report.

CHAPTER VIII

Chemical Symbols and Formulas

The chemical sign for an atom is called a **symbol**, thus C, O, H, Cl, Zn, K, Mn, Fe are symbols for the elements carbon, oxygen, hydrogen, chlorine, zinc, potassium, manganese, and iron respectively. It will be noticed that the symbol for an atom is either a single capital letter, or consists of a capital and a small letter. The symbol for potassium (K) is the first letter of the word kalium, another name for potassium. The symbol for iron (Fe) is taken from the word ferrum, the Latin name for iron. Strictly the symbol denotes a single atom, or unit mass of the element, but it is quite customary to use symbols as abbreviations of the names of the elements. Chemical symbols should *not* be marked, as other abbreviations are, by placing a period after each. The chemical sign for a molecule is called a **formula**. The formula for an element has only one symbol in it, the number of atoms in the molecule being indicated by a small figure placed to the right of the symbol, and a little lower; thus H_2 and O_2 are formulas for hydrogen and oxygen. Chemists having found that these elements, as well as many of the others, have two atoms in each

molecule. The formula for a compound substan has a symbol for each of the different *kinds* atoms in the molecule.

The number of atoms of each kind is shown figures; thus the formula for carbonic acid gas CO_2. This formula records the fact that chemic analysis has shown that each molecule of this g is made up of one atom of carbon and two atom of oxygen. We have been able to show, by simp experiments (see Chapter IV), that carbonic ac gas consists of carbon and oxygen chemical united, that is, that each molecule of the gas con sists of one or more atoms of carbon and oxygen. To prove the *number* of atoms of eac element in a molecule is quite beyond our presen powers, and so we shall have to accept the quant tative part of the formula in this and all othe cases, on the authority of the expert chemists wh have worked it out; but we shall always try t determine the *qualitative* part, the *kinds of atoms* i the molecule, by our own experiments.

CHAPTER IX

VALENCE, EQUATIONS, AND CHEMICAL NAMES

We found that water consists of hydrogen and oxygen. Its formula (H_2O) means that two atoms of hydrogen unite with one of oxygen to form the smallest particle, the molecule, of water. One atom of oxygen is capable of uniting with two of hydrogen to form a molecule of water, while in CO_2 it takes two oxygen atoms to bind one atom of carbon into a molecule of carbonic acid gas. It has been found that the atoms of different elements often *differ* as to the number of other atoms of any particular element they are capable of uniting with when they are being grouped into molecules. This property of atoms is called **valence or quantivalence.**

Hydrogen is taken as the standard of valence; its valence is said to be *one*. As the oxygen atom is capable of uniting with two hydrogen atoms to form a complete molecule of water, the valence of oxygen is said to be *two*. Since the carbon atom can unite with (saturate) two atoms of oxygen, and each atom of oxygen can saturate two atoms of hydrogen (as in H_2O), the valence of carbon is four, for the two atoms of oxygen which unite with the carbon atom in CO_2 are equivalent, in regard to valence, to four atoms of hydrogen. Thus there is

a molecule CH_4 (marsh gas), but no *substan* whose formula is CH_5 or CH_3.

Chemical Equations. Any change in whi chemical union or chemical separation takes pla is called a **chemical change** or **reaction.**

When carbon burns in oxygen, as we have see chemical union takes place, and a gas whose formu is CO_2 is produced. Assuming the quantitati correctness of this formula, this reaction may expressed by a *chemical equation*, thus:—

Carbon + oxygen = Carbon dioxide (carbonic acid gas).

$$C + 2O = CO_2.$$

Of course the action expressed by this equati takes place once for each molecule of CO_2 forme In burning even a small piece of carbon, it wou happen millions of times. To express the reacti which takes place when hydrogen is burning, use the equation:—

Hydrogen + Oxygen = Hydric oxide (water).

$$2H + O = H_2O.$$

Chemical Names. The chemical name of simple substance (element) is always a single wor There are nearly 80 chemical elements known. T chemical name of a compound substance is usua made up of *two* words. As a rule, the first wo denotes one of its elements, and the second wo the other element or elements. Prefixes are us to denote the number of atoms in a molecule of t compound. Thus, the chemical name of carbon

acid gas (CO_2) is carbon dioxide. Here, the syllable *ox* denotes oxygen, and the prefix *di* implies that there are only two oxygen atoms in the molecule. The ending *ide* signifies that there are two *kinds* of atoms in this compound. Similarly, the chemical name for water is hydric oxide or hydrogen monoxide.

In the name **potassium chlorate** ($KClO_3$) for chlorate of potash, the syllable *chlor* denotes the element *chlorine*, and the ending *ate* implies that there are three elements in the compound. Since oxygen is usually present in compounds which contain three elements, the ending *ate*, as a rule, indicates the element oxygen as the third element in the compound.

CHAPTER X

The Gases of the Air

(*a*) What element of wood will burn, and wha
constituent of wood will not burn ?

Experiment 1. Shake a little clear lime-wate
through a bottle of air.

Set fire to one end of a long splinter of dr
hardwood, and hold it in the bottle to burn clos
above the lime-water for half a minute, with a
little smoke as possible. Then cover the mouth o
the bottle quickly with a wet slip of glass, an
shake the lime-water up and down through th
gas in the bottle. If a decided change does no
appear in the lime-water, repeat the burning an
shaking.

(*b*) Describe the visible results, and account fo
them.

(*c*) Show how the new gas must have bee
formed.

(*d*) Argue from this experiment to show that th
air contains oxygen.

(*e*) Show also that the air contains some othe
gas different from oxygen.

Left: Preparing Nitrogen from the Air, Chap. XI. Right: Proof that Air Contains Oxygen, Chap. X.

(*f*) The other gas mixed with oxygen in the air is mainly, but not entirely, nitrogen.

(*g*) Point out, then, some of the properties of nitrogen.

(*h*) Tell why nitrogen is called a simple substance.

(*i*) Explain why the burning carbon did not unite chemically with the nitrogen of the air, rather than with the oxygen.

Experiment 2. Put about an inch of clear lime-water into a wide-mouth bottle, cover the mouth of the bottle with a slip of glass, invert the bottle in a saucer-like dish, containing lime-water to the depth of an inch or near it, remove the glass slip and leave the bottle undisturbed for two or three days. Notice whether the same change takes place at the surface of the lime-water inside the bottle as at the surface of the lime-water around the bottle in the dish.

Experiment 3. Ignite one end of a dry splinter of hardwood, and hold a deep, wide-mouth bottle mouth down close above the flame, for about a minute, to catch the carbon dioxide as it rises from the flame. Promptly set the bottle with its mouth in a dish containing lime-water, as in experiment 2. The heated gas should contract, and the pressure of the air on the surface of the lime-water force some of it up into the bottle. If no lime-water

rises into the bottle, repeat the operation mo carefully. Leave the apparatus undisturbed, a note the change at the surface of the lime-water the bottle and around it. This experiment shou go on simultaneously with experiment 2.

(*k*) Explain the results of experiments 2 and and argue from them that the air contains sor carbon dioxide.

Experiment 4. Fill a glass jar with water, a another with ice and water or a mixture of snow (powdered ice) and salt, and in a little while rub t outside of the jar with the hand.

(*l*) Show from this experiment that the air co tains water in the state of an invisible gas (stean

(*m*) Give reasons for thinking that the four gas we have found in the air are or are not chemical united.

(*n*) Show whether the air contains free hydrog to any perceptible amount.

⁂ Experiment 1 evidently does not show that the contains no carbon dioxide, but only that there is not enou of that gas in a bottle of air to turn the lime-water whi

The gases of the air act independently of each other, as they were free. When carbon burns in air, we find that unites with the oxygen there to form carbon dioxide, just it would do in pure oxygen, only more slowly. The nitrog of the air displays its own properties by hindering the bu ing of the carbon, and by not uniting with the carbon. T carbon dioxide of the air acts upon the lime-water just as t free gas does. The invisible water vapour in the air is co

densed into a liquid by cold in the same manner as unmixed steam would be.

The air contains nearly four times as much nitrogen as oxygen, by weight. The other constituents of the air, of which there are a number, form a very small part of it; but some of them, as carbon dioxide and water vapour, are very important. In 1894, an elementary gas called argon was discovered in the air. It is similar in its properties to nitrogen, but is still less active chemically. It forms about 1% of the air. Ozone (O_3), a very energetic form of oxygen, occurs in the air in very small proportion. It may be formed from the ordinary oxygen by electrical discharges.

CHAPTER XI

More About the Gases of the Air

Experiment 1. Hold a *cool, dry* tumbler or wide-mouth bottle, mouth down, above a small alcohol flame (flame of a spirit lamp), and identify by touch and taste the liquid which soon collects on the glass inside the tumbler or bottle.

Experiment 2. Again hold the tumbler or the bottle mouth down, as before, above the flame, not very close, lest you make the glass too hot, and cover its mouth tightly with a wet slip of glass or with the palm of the hand. Turn it mouth up, empty a little lime-water into it, at once cover its mouth again, and shake the lime-water up and down. If no decided change appears in the lime-water, repeat the experiment.

(*a*) Show from these two experiments what two invisible substances rise out of the alcohol flame into the air. Give their common and chemical names. Why did one of these substances condense on the glass and the other not? Why did you not collect any alcohol above the alcohol flame in either experiment?

(*b*) Give proofs that chemical union was taking place in the flame, and point out what element or elements of the alcohol and of the air were taking part in the chemical union.

Experiment 3. Twist the end of a wire about a *small* pellet of sponge or cotton, bend the wire into the shape of a capital U with a handle, soak the cotton in ordinary alcohol or methylated spirits. Hold the bent wire with the base of the U on the bottom of a dish containing two or three inches of lime-water. Ignite the alcohol in the sponge or cotton, and lower a wide-mouth bottle, mouth down, over the flame, until the mouth of the bottle enters the lime-water and rests upon the bottom of the dish. Draw the wire and cotton out of the bottle, without raising the mouth of the bottle above the lime-water. Cover the bottle's mouth tightly (with the hand or otherwise). Turn it mouth up, and slowly shake the lime-water which rose into the bottle up and down, holding the cover close upon the mouth of the bottle. Plunge a blazing test stick into the gas in the bottle as you move the cover aside.

If you perform this experiment with care and judgment, the flame of the stick will be instantly extinguished when it enters the gas in the bottle.

Experiment 4. Repeat experiment 3 with this variation: instead of using the gas left in the bottle (after shaking the lime-water through it) to

extinguish a flame, turn the bottle mouth down in a deep basin of water, remove the glass slip, and empty the gas upward into a smaller wide-mouth bottle (which the gas will fill), inverted, full of water, in the water in the basin. This may be done by bringing the mouth of the larger bottle under the mouth of the smaller, and tipping it so that the gas will rise out of the larger bottle, and displace the water in the upper bottle.

Then cover the mouth of the smaller bottle, remove it from the basin, and shake a little lime-water through it. The lime-water should remain clear, or nearly so.

(*c*) Show what changes were made in the air of the bottle by the alcohol flame, and by the lime-water.

(*d*) Show what gaseous element of the air (mixed, however, with a small proportion of other gases) remained in the bottle after the lime-water had been shaken through it.

⁂ These experiments will make it plain to the student that an alcohol flame, like the flame of burning wood, sends into the surrounding air both carbon dioxide and water in the gaseous form, and removes free oxygen from the air, while the air apparently suffers no loss of nitrogen. If the lime-water in experiment 4 absorbs all the carbon dioxide produced by the flame, the gas which remains will show no trace of carbon dioxide when tested by the same method. The amount of lime-water which rises into the bottle in experiments 3 and 4 will depend on the quantity of air which is forced out of the bottle (in bubbles) on account of the expansion of the air there by the heat of the alcohol flame. These experiments are intended to illustrate some of the distinctive properties and inter-relations of the gases in the air.

CHAPTER XII

Oxidation, Combustion, and Respiration

(*a*) What compound substance is produced by burning carbon in the air? by burning hydrogen in the air?

Def. A compound substance consisting of oxygen and one other element only is called an **oxide.** Why are carbonic acid gas and water classified as oxides? What are their names as oxides?

Def. The chemical union of any substance with oxygen is called **oxidation.** Mention two cases of oxidation which occurred in your experiments.

Def. When a compound substance is deprived of a part or the whole of the oxygen chemically united with its other element or elements, it is said to undergo **reduction** or **deoxidation.** What case of reduction occurred in Experiment 2, Chapter VII? What substance was used to aid the heat in releasing the oxygen—that is, in the reduction?

(*b*) Of what three elements does wood consist? Show whether wood is an oxide.

Experiment 1. Put an inch of alcohol into a test tube, insert tightly a cork containing a straight

glass delivery tube about 6 in. long, heat carefully the alcohol in the tube, and hold a *cool* tumbler mouth down, over the mouth of the delivery tube Identify by touch and taste the liquid which collects on the inside of the tumbler.

Experiment 2. Heat the alcohol in the test tube again, and instead of holding a tumbler over the escaping vapour, set fire to it as it issues from the delivery tube, and try whether you can collect alcohol in a tumbler inverted over the flame.

NOTE.—On account of the inflammability of alcohol these two experiments had better be performed at the lecture table, before the class, by the teacher.

(*c*) Explain why you could not collect alcohol above the alcohol flame, and show what liquid you did collect.

(*d*) What gas (or invisible vapour) fills the alcohol flame? Show from experiment that a flame is a *burning gas.*

(*e*) What two invisible substances rise into the air from the alcohol flame? If you have forgotten collect and test them as in Chapter XI.

(*f*) Explain why the substances which rise from alcohol flame are oxides, and point out how they were formed.

(*g*) Which should weigh more—the alcohol which was burned, or the two oxides which were produced by burning it? Explain.

DEF. When oxidation is so rapid and intense that both heat and light are produced, the process is called **burning** or **combustion.**

Mention several cases of combustion which you have observed.

Experiment 3. Grasp the back of your chair or some object on the table, and account for the temperature sensation at first perceived.

Experiment 4. Blow your breath, by means of a tube, through a little clear lime-water in a tumbler, till you get a decided result.

(*h*) Point out the connection between the temperature of the body and the result of this experiment, and give proofs that the temperature of the body is maintained by heat of chemical union (oxidation).

(*i*) Mention a case in which oxidation produces heat but no light.

⁂ The temperature to which a substance must be raised in order to set it burning is called the *kindling* or *ignition* point. Some bodies take fire at a much lower temperature than others. The molecules of the substance to be burned must be made to vibrate more or less rapidly before the atoms composing them will loosen their hold on each other and unite with oxygen atoms from the oxygen molecules of the surrounding air. When one end of a splinter of dry wood has been raised to the ignition point by heat from an outside source, the heat of chemical union produced by burning this first part brings the wood close to it to the ignition point, and so on, till the whole splinter has been burned, that is, till the whole of its carbon has united with oxygen from the air.

The fact that our food, both animal and vegetable, will char when heated, shows that it contains charcoal (carbon). The union of the carbon derived from our food with the oxygen that we inhale with the air takes place in all parts of the body, and it is mainly the heat thus produced which maintains the body at a nearly even temperature (98.4° F.), even when the temperature of the air about us is below the freezing point.

Stoves and furnaces are contrivances for producing heat by the chemical union of carbon and oxygen—the carbon being supplied by the wood and coal, the oxygen by the air which enters by the draft.

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LEFT: BURNING GASES FROM THE DESTRUCTIVE DISTILLATION OF WOOD.
RIGHT: COLLECTING GASES ARISING FROM THE FLAME OF BURNING WOOD.

CHAPTER XIII

THE BURNING AND THE DESTRUCTIVE DISTILLATION OF WOOD

Experiment 1. Burn a splinter of dry hardwood held obliquely just below the mouth of a cool tumbler inverted above the flame, and identify by touch and taste the liquid which collects on the inside of the tumbler.

Again hold the same tumbler, mouth down, over the flame of a burning splinter, cover the mouth of the tumbler with a damp slip of glass or with your hand, turn it mouth up, pour in a little clear lime-water, and shake it through the tumbler. A 6 oz. wide-mouth bottle may be used instead of a tumbler.

(*a*) Show from the preceding experiment what two substances rise invisibly out of the flame of burning wood, and account for the fact.

(*b*) Show why neither of the two substances produced by burning wood will themselves burn. Explain how water and carbon dioxide extinguish fire when used for that purpose.

Experiment 2. Try whether a splinter of wood will burn as well in a narrow test tube as in a tumbler or wide-mouth bottle. Explain.

LEFT: BURNING GASES FROM THE DESTRUCTIVE DISTILLATION OF WOOD.
RIGHT: COLLECTING GASES ARISING FROM THE FLAME OF BURNING WOOD.

Experiment 3. Fill a test tube (5 in. × $\frac{1}{2}$ in., or 6 in. × $\frac{3}{4}$ in.) to within 1 or 2 inches of its mouth with cotton wool packed in rather tightly, or (better) with dry sawdust. The cotton wool is quite pure wood or cellulose; the sawdust is more impure, but the impurities mostly contain the same elements as wood. Hold the test tube by means of a wire twisted around it near its mouth (leave a few inches of wire extending out for a handle) and heat the test tube in the flame of a gas burner or spirit lamp. Put a piece of blue litmus paper just inside the mouth of the tube, and leave it there till the paper changes colour. Soon after the cotton or sawdust begins to char, you will be able to set fire to the gases escaping from the test tube. To ignite the gas hold a burning match or splinter close above the upper edge of the mouth of the test tube; for the heated gases rise straight up into the air. Note the change in the colour and brightness of the flame at different stages of the process. Keep on heating the test tube as long as the escaping gas will burn at its mouth. Before the flame dies out, find as you did in experiment 1 what two invisible gases rise out of it.

⁂ When wood is thus decomposed by heat, *in the absence of air*, the process is called dry or destructive distillation. The air in the test tube was soon driven out by the gases escaping from the wood. We can see that the wood, although it consists only of carbon, hydrogen, and oxygen, breaks up into a number of different substances besides carbon and water. The substance which turned the blue litmus red is called an acid. The combustible gas was really a mixture of

various gases, one of which may be hydrogen, the flame of which, as you know, gives but little light. The gas which burns with a blue flame is called carbon monoxide (CO), and there are other combustible gases, for instance, marsh gas (CH_4) and acetylene gas (C_2H_2), produced from wood in varying amounts.

Wood alcohol, charcoal, and acetic acid (the acid which makes vinegar sour), are the chief chemical products obtained by the dry distillation of hardwoods on a large scale. Here you may try whether vinegar will act on blue litmus as did the watery liquid you got by distilling the wood. Vinegar consists essentially of acetic acid, diluted with water, and though it is often obtained by the fermentation of alcohol, can be made by diluting acetic acid produced by the destructive distillation of wood.

It is evident that not only the combustible gases, but the wood alcohol, acetic acid, and other substances into which wood breaks up must consist of one, of two, or of all the three elements in wood (C, H, and O), and no others.

The reason that some of the gases given off will burn, must be that they contain no oxygen, or not enough to saturate them. When they were burning at the mouth of the test tube they were saturating themselves with oxygen from the air. One or more of these gases must contain carbon, else the flame we got by burning them would not have given off carbon dioxide. The gases given off by the flame (CO_2 and H_2O) will not burn because they are oxides in which the carbon and hydrogen are saturated with oxygen. Carbon monoxide will burn because the carbon in it is not saturated with oxygen, but is capable of uniting with as much more oxygen from the air as it brought with it from the wood. This it does when it burns, and is thus converted into carbon dioxide.

We can now see that it is better to say that pure wood consists of carbon and the *elements* of water than to say that wood consists of carbon and *water*. When wood is decomposed by heat, the atoms (C, H, and O) group themselves in different ways and numbers forming molecules of the various substances produced in the distillation of wood. The charred mass which remains after destructive distillation, although large, does not contain all the charcoal which was in the

wood, for part of it was taken to form the liquid and gaseous substances which were formed in the process of distillation.

In the destructive distillation of wood, there is nothing taken from the air; the products are many, but they are all formed from the elements of the wood. Some of them are therefore deficient in oxygen, and are combustible.

When wood is burned, oxygen is taken from the air, and there are only two final products (CO_2 and H_2O) which are both saturated with oxygen and are therefore incombustible. The ash which remains after the complete combustion of the wood was not a chemical part of the wood, but an impurity. The particles of ash were not *in* the molecules of wood but *between* them.

We do not, we cannot, burn wood itself directly. The great flames which we see when a forest or a wooden house is on fire, must be due to the burning of the combustible gases driven out of the wood by the heat. Indeed, we may expect that any solid or liquid substance which burns with a flame will yield a combustible gas when heated in the absence of air.

CHAPTER XIV

METALS AND ACIDS

Experiment 1. Find whether zinc, iron, charcoal, and oxygen are good conductors of electricity and good conductors of heat. Also note the colour and lustre of each.

(*a*) Record results.

DEF. A simple substance (or chemical element) which is a good conductor of heat, a good conductor of electricity, and which shows on an untarnished surface a metallic lustre, is called a **metal**, or **metallic element.**

DEF. A *simple* substance which does not possess all *three* of these properties, is called a **non-metal**, or **non-metallic element.**

(*b*) Classify the four elements mentioned above as metals or non-metals, giving your reasons.

(*c*) Show whether wood and water are metals or non-metals, or whether they belong to neither class.

Experiment 2. Place in a glass dish about a tablespoonful of water. Take, on a stirring rod, a drop or two of hydrochloric acid from the

bottle, and stir the acid in with the water. Observe whether any gas is set free when the water mixes with the acid. Taste the solution, and note its effect on blue and red litmus paper.

Experiment 3. Try a like experiment with sulphuric acid, using as before only a drop or two of the acid in a tablespoonful of water (do not swallow any of either solution in finding the taste).

(*d*) Record the results of experiments 2 and 3.

Experiment 4. Cover an inch of zinc in a test tube with water, and note the effect. Then pour the water off, and cover the zinc with dilute hydrochloric acid from the bottle. Test, with a glowing and with a blazing test stick, the gas thus set free. Collect some of the gas in an inverted tumbler, and set it on fire.

Experiment 5. Saturate with water about a teaspoonful of iron filings in a 2 oz. bottle or small tumbler, then add a teaspoonful (by estimate, not in a spoon) of dilute sulphuric acid; cover the mouth of the bottle or tumbler with a wet slip of glass. In a little while try to set fire to the gas in the tumbler, with a blazing test stick.

(*e*) Show what gas was set free in each case, and what it came out of.

(*f*) Point out what chemical property both of the metals displayed in the last two experiments.

(*g*) Point out what element enters into the composition of both acids, and whether there is anything else in the acids.

DEF. That part of each acid which is united with hydrogen to form a molecule of the acid is called **an acid radical.**

⁂ If the water had set a gas free from either acid, or if the acid had set free either of the gases of the water, the free gas would have risen in bubbles through the water, as it did when the metal and acid were both present. We should remember, however, that if a gas is set free in water by a *chemical* change it will continue to rise until the reaction is over; if the bubbles cease to rise very soon, we may suspect some cause other than a chemical change.

It is evident that neither of the acids consists of hydrogen alone, for the acid is quite different in its properties from hydrogen. So each acid must contain some other element or elements which the student has not yet discovered for himself. This as yet undiscovered part of the acid is the *acid radical.*

CHAPTER XV

Analysis of Hydrochloric Acid

Experiment 1. Cover about an inch (depth) of zinc in a test tube with water. Pour off the water, and cover the zinc with dilute hydrochloric (muriatic) acid. Try whether the gas thus set free can be set on fire by a glowing test stick—by a blazing test stick.

(*a*) Show what this gas probably is.

(*b*) Show which substance the gas came out of—the zinc, the water, or the acid.

Experiment 2. Add to one-third of an inch (depth) of black oxide of manganese (manganese dioxide) in a test tube, about half an inch of dilute hydrochloric acid. By means of a bent wire, suspend *together* a small piece of red litmus paper, of blue litmus paper, and of coloured cotton, all slightly dampened with water, inside the mouth of the test tube. As soon as the dilute acid, aided by stirring, if necessary, has saturated the black oxide, *slightly warm* the mixture in the test tube and *cautiously* smell the gas set free. This is a poisonous gas.

Experiment 3. Continue to heat the tube *very slowly*. Note the colour, as seen through the glass

tube, of the gas which fills the large bubbles which rise slowly. As soon as a decided effect is observed in the paper and cloth, remove them. Cork the test tube *loosely* and set it in a stand. Open the windows for a few minutes.

(*c*) What distinctive properties of this gas did you observe?

(*d*) How can you distinguish this gas (**chlorine**) from oxygen? from nitrogen? from hydrogen? from carbonic acid gas (carbon dioxide)?

(*e*) Tell why chlorine is regarded as a chemical element.

(*f*) Show what substance this element came out of, and what it was chemically united with before it was set free.

(*g*) Argue out from these experiments the elementary composition of hydrochloric acid, and give its chemical name.

Experiment 4. Hold by a wire catch a small piece of blue litmus paper in the mouth of the bottle of hydrochloric acid, without touching the glass, till you observe a change of colour in the paper; also note the smell of the gas which escapes from this bottle.

Try whether you can get the same results in the mouth of a bottle of sulphuric acid. Also stand a splinter of wood, for a minute, in strong sulphuric acid.

(*h*) Point out what changed the colour of the litmus paper, and account for the different results.

*** Experiment 4 illustrates the fact that hydrochloric acid is a *gas* with an irritating odour. The liquid we buy as hydrochloric acid is really a solution of the gas in water. The formula for the acid gas is HCl, the valence of chlorine being *1*, the same as the valence of hydrogen. Sulphuric acid is a heavy, non-volatile liquid which does not evaporate from or with the water with which it is usually diluted, as hydrochloric acid does. Sulphuric acid is very corrosive and poisonous. Great care should be exercised in experimenting with it. When strong it would cause deep and permanent scars on the face or hands.

As an example of reasoning from experiment, we may take the argument asked for in the preceding exercise (*g*): The metal zinc being a simple substance, the hydrogen could not have come out of it. Since the zinc did not set hydrogen free from the water (experiment 1), nor is hydrogen set free when the acid is mixed with water, the *zinc* must have set the hydrogen free, not from the water, but from the acid. When the manganese dioxide was mixed with the dilute acid, chlorine was set free. Now the black oxide consists, as its name implies, of manganese and oxygen, and water of hydrogen and oxygen. Since neither of these substances contains chlorine, the chlorine must have come out of the acid. As we have obtained both hydrogen and chlorine from the acid, and have found no indication of any other element in it, we may conclude, for the present at least, that hydrochloric acid consists of hydrogen and chlorine only, and that its chemical name is hydrogen chloride, or hydric chloride.

Oral Exercises

Deduce the following equations from experiments in this chapter:—

(1) $Zn + 2HCl = ZnCl_2 + 2H$. (Expt. 1).

(2) $MnO_2 + 4HCl = MnCl_2 + 2H_2O + 2Cl$. (Expts. 2 and 3).

In arguing (deducing) that the reactions expressed here actually took place in the experiments, the student may assume the correctness of the formulas as given.

Manganese being a metal, we may suppose that it would take the place of the hydrogen or part of the hydrogen of the acid, uniting with the acid radical (Cl) to form manganese chloride ($MnCl_2$). Since neither the oxygen of the manganese dioxide nor the hydrogen of the acid were set free, we may infer that they united to form water ($4H$ and $O_2 = 2H_2O$), the rest of the chlorine ($2Cl$) being set free, which accounts for the chlorine which rose from the mixture.

CHAPTER XVI

Preparation of a Salt

(*a*) *Review.* What two elements did you find in hydrochloric acid? Give the properties by which you can distinguish them from other elements.

Experiment 1. Put an inch of granulated zinc into a test tube, empty it out on a filter paper, and balance it on the scales. Put the zinc again into the test tube, cover it with dilute hydrochloric acid, and test the gas, as it issues from the test tube, with a glowing and a blazing test stick. Collect some of the gas and burn it.

(*b*) Name the gas, and tell what you learned about it before.

Experiment 2. When the bubbling (effervescence) has nearly ceased, pour the liquid off the zinc into a tumbler, cover the zinc with acid again, and find whether any chlorine is set free.

(*c*) Give your reasons for thinking that chlorine was or was not set free.

Experiment 3. As soon as the chemical action in the test tube has about ceased, empty the liquid off the zinc into the tumbler, rinse the zinc, while still

in the test tube, with water, and then heat it on an evaporating dish till it is quite dry. Replace the zinc on the filter paper, and try whether it has gained or lost in weight, and how much.

(*d*) Account for the change in weight, show what the gain or loss is the weight of, and explain how it came about that chlorine was or was not set free in experiment 2.

(*e*) Explain why the test tube becomes hot at the bottom in experiment 1.

Experiment 4. Pour about a tablespoonful (estimated in a test tube) of the liquid you poured off the zinc out of the tumbler into an evaporating dish, and evaporate it to dryness. Find whether the dry residue is the same as either of the three substances you put into the test tube. If you taste the residue, do so cautiously.

(*f*) Point out where and when this residue was formed, and why you could not see it before the evaporation.

(*g*) Show whether the residue contains either of the elements of the acid, and what other element or elements it contains.

(*h*) Why can you not perceive either of these elements?

(*i*) Give the chemical name of the residue in the dish.

(*j*) Why is it called a salt?

Def. A salt is a compound substance consisting of a metal and an acid radical.

*** Since the zinc bichloride was formed by a metal (Zn) taking the place of the hydrogen of hydrochloric acid, and uniting with the radical (Cl) of that acid, it is called a salt of hydrochloric acid. The name chloride is evidently common to all the salts of hydrochloric acid.

It can be shown from experiment 2 that the weight of zinc which can unite with a certain amount of chlorine is limited, that is, the two elements unite in *definite proportions.* The student should note whether this is a constant characteristic of *chemical union.*

Oral Exercise

1. Deduce this equation from the preceding experiment:—

$$\begin{array}{ccccccc} \text{Metal} & + & \text{Acid} & = & \text{Salt} & + & \text{Hydrogen} \\ Zn & + & 2HCl & = & ZnCl_2 & + & 2H. \end{array}$$

N.B.—It should be made very clear that a chemical equation does not prove anything, but, before it can be depended upon, must be itself proved correct by argument based on experiment.

CHAPTER XVII

Synthesis of Acidic Oxides and Acids

Experiment 1. Put quarter of an inch (depth) of water into a bottle or flask, burn, with as little smoke as possible, the end of a splinter of dry wood in the air of the bottle above the water. Raise the stick out of the bottle. Cover the mouth of the bottle with a wet slip of glass or the hand, shake the water up and down through the bottle, and find by testing whether hydrogen or oxygen was set free.

Experiment 2. Add just enough blue litmus paper (or, better, litmus solution) to the solution in the bottle to distinctly colour it. If the colour of the litmus does not change, burn wood as before in the bottle, and shake the solution through the gas.

(*a*) State briefly the results of experiments 1 and 2.

(*b*) Argue to show the elementary composition of the substance which changed the colour of the litmus in experiment 2.

Experiment 3. Burn in the air, over a plate, without smoke, if possible, a little melted sulphur held in a heated wire coil. Note the smell of the

gas (not of the smoke) which rises from the flame. Observe the colour of the flame, and consider how the gas was formed which rises out of the flame, and what gas burns *in* the flame but does not rise out of it.

Experiment 4. Burn sulphur as before, and collect the gas produced, by holding a wide-mouth bottle, mouth down, close above the flame. Cover the mouth of the bottle as before, and shake a little water through the bottle. Taste the solution, and add enough blue litmus to colour it.

(*c*) Point out the probable composition of the gas produced in experiment 3. Contrast the gas produced by this flame with carbonic acid gas (CO_2).

(*d*) Argue out the composition of the substance which changed the colour of the litmus in experiment 4.

(*e*) Give the common and chemical names of the gases you obtained by burning the sulphur and the charcoal of the wood, and of the two substances which changed the colour of the litmus.

(*f*) Explain why carbonic acid gas and sulphurous acid gas are called acidic oxides.

DEF. The oxide of a non-metal, which will unite with water to form an acid, is called an acidic oxide.

(*g*) How do carbonic acid gas (carbon dioxide), and sulphurous acid gas (sulphur dioxide), differ in

composition from carbonic *acid* and sulphurous *acid*, respectively?

DEF. An acid is a compound substance, consisting of hydrogen and an acid radical. An acid usually has a sour taste, and turns blue litmus red.

(*h*) Of what two elements do the radicals of carbonic acid and sulphurous acid, respectively, consist? Why are they called *compound* radicals, while the radical of hydrochloric acid is called a *simple* radical?

Oral Exercises

Justify the following equations by the experiments in this chapter:—

(1) $C + 2O = CO_2$.
(2) $S + 2O = SO_2$.
(3) Acidic Oxide + Water = Acid.
$CO_2 + H_2O = H_2CO_3$ (carbonic acid).
(4) $SO_2 + H_2O = H_2SO_3$ (sulphurous acid).

*** The radical (CO_3) of carbonic acid (hydric carbonate, H_2CO_3) is called the carbonate radical. Similarly, SO_3, the radical of sulphurous acid, is called the sulphite radical. The chemical name of sulphurous acid, hydric *sulphite*, distinguishes it from sulphuric acid, hydric *sulphate* (H_2SO_4), which consists of the same three elements, but contains more oxygen. The endings *ous* and *ite* denote that sulphurous acid contains less oxygen than does hydric sulphate (sulphuric acid).

CHAPTER XVIII

Preparation of Basic Oxides and Bases

(*a*) *Review.* Tell how to make carbonic acid, beginning with a piece of carbon or of wood, and how to use a piece of sulphur in preparing sulphurous acid. Of what two oxides, and of what three elements does each of these acids consist?

(*b*) Give reasons for classifying magnesium (Mg) as a metal.

Experiment 1. Hold a piece of magnesium ribbon or wire above a glass dish, and set fire to it there. Catch the smoke which rises from the fire on a slip of glass, and let the ash-like product drop into the dish.

(*c*) Reason out the probable composition of the ash and the smoke, and give their chemical name.

Experiment 2. Wet the ash and the smoke with a little water, and press a piece of damp red litmus paper into the wet mixture, and leave it there till the colour changes.

(*d*) Point out where the magnesium you burned is now, and why you cannot see it.

(*e*) Give reasons to show that lime is not a metal. (See specimen of lime.)

Experiment 3. Thoroughly dampen with water a *small* piece of lime in a glass dish, and test with litmus paper.

(*f*) Record the results of experiments 2 and 3.

(*g*) Argue from these experiments that lime is the oxide of a metal.

Experiment 4. Crush a small piece of lime in about a teaspoonful of hydrochloric acid in a glass dish, and when the whole or a part of the lime has dissolved hold a drop of the solution by a little coil of fine iron wire in the flame of a lamp or burner.

(*h*) What flame colour did you get? This flame colour indicates the presence of a metal called calcium (Ca). Why can you not see the metal calcium in the lime?

Experiment 5. Try whether the water or the acid will give this flame colour.

(*i*) Argue out the composition of lime, and give its chemical name. (See experiments 1 and 2.)

Experiment 6. Balance a larger piece of lime (unslacked lime, quicklime) in a bowl on the scales. Then soak it in cold water and, *before it crumbles to*

pieces, replace it *all* in the bowl, and cover the top of the bowl with an inverted dish.

Experiment 7. When the lime begins to get hot, raise the dish a little and test to find whether hydrogen or oxygen is set free in the bowl, and identify the liquid which collected on the dish. *Then leave the bowl uncovered.*

(*j*) Explain the heat and the other results.

Experiment 8. When the contents of the bowl become *quite dry*, find whether the weight has changed, and how much.

(*k*) Show what the difference in weight is the weight of.

(*l*) Taste the dry powder in the bowl, and test it with damp red litmus paper.

(*m*) Argue out the elementary composition of this dry powder, and give its common and chemical names.

(*n*) Point out the probable composition and chemical name of the substance in experiment 2 which turned the red litmus blue.

(*o*) The two substances which turned the red litmus blue are called **bases**.

DEF. The oxide of a metal which will unite chemically with water to form a base is called a **basic oxide**. Name two examples.

Oral Exercises

Point out in which experiments the following reactions occur:—

(1) $Mg + O = MgO$.

Basic Oxide + Water = Base.

(2) $MgO + H_2O = MgO_2H_2$ or $Mg(OH)_2$ (magnesium hydrate, or magnesium hydroxide).

Basic Oxide + Water = Base.

(3) $CaO + H_2O = CaO_2H_2$, or $Ca(OH)_2$ (calcium hydrate, or calcium hydroxide).

(The group of two atoms OH is called *hydroxyl*.)

DEF. A base is a compound substance composed of a metal and hydroxyl. It usually has an alkaline taste, and turns red litmus blue. A base is formed when the oxide of a metal unites with water.

CHAPTER XIX

REACTION BETWEEN A BASE AND AN ACID

(*a*) How do you argue that lime is the oxide of a metal?

(*b*) How do you show what the metal in lime is?

(*c*) Why is lime called a basic oxide? Give its chemical name.

(*d*) Show what elements are in water-slacked lime. Give its chemical name, and classify it.

Experiment 1. Put about half an inch of water into a small bottle, add enough blue litmus solution to make the mixture look quite blue; then blow your breath by means of a tube through the mixture until the colour changes to a decided red.

(*e*) Show what acid changed the colour of the litmus, and how this acid was formed in the water.

Experiment 2. Put about an inch of clear lime-water into a bottle, and drop a small bit of red litmus paper into it.

(*f*) As soon as the colour of the paper changes, show what base did it. (Remember that lime-

water is made by dissolving water-slacked lime, $Ca(OH)_2$, in water.)

Experiment 3. Blow your breath by means of a tube through the lime-water till it looks white. Test to find whether this process sets hydrogen free. Keep on passing your breath through the mixture until you can make it no whiter, and then cease. Allow the white precipitate to settle to the bottom of the bottle.

N.B.—When a solid substance forms in a liquid, as in this case, the solid is called a *precipitate*.

(*g*) Show what elements this white precipitate is composed of, and give its common and chemical names, with the reasons.

(*h*) Show what part of the base is in this precipitate, and what elements of the acid are in it. Also point out what became of the rest of the base and the rest of the acid.

(*i*) Why is the precipitate called a *salt?* (See definition of salt.)

(*j*) What two compound substances were produced when you mixed the base and the acid?

(*k*) Why are an acid and a base said to neutralise each other?

(*l*) If you were to stain your clothes with acid, what remedy would you apply at once? Explain.

⁂ As not one of the elements of the base or of the acid is set free in experiment 3, we have to look back to other experiments for help in interpreting this reaction. That a chemical reaction did occur is shown by the formation of a new substance—the white precipitate. In previous experiments we found that the metals, iron and zinc, replaced the hydrogen of acids, and united with the acid radicals to form salts, thus setting the hydrogen of the acids free. In *this* experiment we may presume that the metal calcium of the base (CaO_2H_2), acted similarly by taking the place of the hydrogen of carbonic acid (H_2CO_3), and uniting with the acid radical, that is, with the carbon and oxygen of the acid, thus forming the salt *calcium carbonate* (carbonate of lime, $CaCO_3$) which salt appeared as a white precipitate. To explain why no hydrogen was set free, we must suppose that the displaced hydrogen of the acid united with the hydrogen and oxygen (the hydroxyl) of the base to form water (H_2O), which water did not appear to the eye because it mingled with the other water in which the base and acid were dissolved. This reaction, then, may be expressed thus:—

BASE	+	ACID	=	SALT	+	WATER
Calcium Hydroxide	+	Hydric Carbonate	=	Calcium Carbonate	+	Water
$Ca(OH)_2$	+	H_2CO_3	=	$CaCO_3$	+	$2HOH$ or $2H_2O$

DEF. A group composed of different kinds of atoms, forming part of a molecule, which acts like a single atom, passing through a chemical change without breaking up, is called a **compound radical.** Thus *hydroxyl* (OH) and the *carbonate radical* (CO_3), as indicated in the above equation, are compound radicals. Compound radicals, like elements, have valence. It can be seen above that the valence of hydroxyl is *one* and that of the carbonate radical *two.*

Exercises

(1) Break a *small* piece from a stick of caustic soda (sodium hydroxide, NaOH), dissolve it in about an ounce of water, taste, and test with litmus. You will find that caustic soda is a strong, soluble base (an *alkali*). Mix this solution, a little at a time, with hydrochloric acid, until the solution is about neutral to litmus, noting whether any hydrogen or oxygen is set free in this reaction.

What evidence can you find that an invisible salt was produced? Render some of the salt visible by rapid evaporation of a part of the solution, and crystallize the rest of it by *slow* evaporation. Deduce and equate the reaction, giving the names and classes of the two factors and the two products of the reaction.

(2) Prepare the salt *sodium sulphate* (Na_2SO_4) by mixing the proper base and acid. Dry the salt and taste it. Equate the reaction.

(3) Prepare the salt ammonium chloride (NH_4Cl, sal ammoniac) by neutralizing the base ammonium hydroxide (NH_4OH, ammonium hydrate, aqua ammoniae) with the acid of this salt. Dry and crystallize the salt, and equate the reaction, giving the names first and the formulas under them.

N.B.—It will be observed that the base NH_4OH differs from the other bases we have used in that it does not contain a metal. The compound radical NH_4 (ammonium), however, behaves chemically like a metal, and with OH forms a base.

(4) Prepare some other salt by mixing its acid and base, and dry the salt. Equate the reaction, giving the names and formulas of the factors and products.

A PARTIAL LIST OF THE ELEMENTS

NAME	SYMBOL	ORDINARY VALENCE
Aluminum or Aluminium	Al	3
Antimony (Stibium)	Sb	3, 5
Arsenic	As	3, 5
Barium	Ba	2
Bismuth	Bi	2
Boron	B	3
Bromine	Br	1
Calcium	Ca	2
Carbon	C	4
Chlorine	Cl	1
Chromium	Cr	3
Cobalt	Co	2
Copper (Cuprum)	Cu	2
Fluorine	F	1
Gold (Aurum)	Au	3
Hydrogen	H	1
Iodine	I	1
Iron (Ferrum)	Fe	2, 3
Lead (Plumbum)	Pb	2
Magnesium	Mg	2
Manganese	Mn	2
Mercury (Hydrargyrum)	Hg	2
Nickel	Ni	2
Nitrogen	N	3, 5
Oxygen	O	2
Phosphorus	P	3, 5
Platinum	Pt	4
Potassium	K	1
Silicon	Si	4
Silver (Argentum)	Ag	1
Strontium	Sr	2
Sulphur	S	2, 4, 6
Tin (Stannum)	Sn	2, 4
Zinc	Zn	2

NOTE.—When the valence of an element is one, it is said to be univalent. In like manner the terms bivalent, trivalent, and quadrivalent denote a valence of *two*, *three*, and *four* respectively.

SET OF APPARATUS AND REAGENTS

For One Student or Two Students Working Together

---

1 Enamelled Metal Basin, about 4 in. deep, or a small Pneumatic Trough.

2 Wide-mouth Prescription Bottles, clear glass; one 2 or 4 oz., one 6 or 8 oz.

1 Wide-mouth Milk Bottle, ½ pint.

2 Glass Stirring Rods.

2 Glass Slips, about 3 in. square.

1 Small Glass Funnel.

1 Test Tube Holder, wire preferred.

1 dozen Test Tubes, 5 x ½ in. or 6 x ¾ in.

1 Test Tube Brush.

2 Delivery Tubes, about 1 ft. long, bent and inserted into stoppers or corks to fit the test tubes when half entered.

1 Enamelled Metal Plate.

2 Small Glass Dishes with flat bottoms.

1 Enamelled Metal or Earthen Bowl.

1 Small Enamelled Spoon.

2 Tumblers, plain and thick.

1 Spirit Lamp nearly full of Methylated Spirits.

1 Enamelled Metallic Saucer, for use as Evaporating Dish.

1 Tripod Stand, to set over Gas Flame or Spirit Lamp and support Evaporating Saucer during evaporations.

1 piece Wire Gauze, to place under Evaporating Dish.

1 dozen Test Sticks (wooden tooth-picks).

1 pint Lime-water in corked bottle.

4 oz. Dilute Hydrochloric Acid, about two volumes of water to one of the strong acid, in glass-stoppered bottle, labelled.

3 oz. Dilute* Sulphuric Acid, about four volumes of water to one of the strong acid, labelled in glass-stoppered bottle.

Blue and Red Litmus Paper, cut into small pieces (about ⅛ or ¼ inch square), in wide-mouth bottle, corked.

Water, on tap, or in pitcher.

*Caution.—In diluting Sulphuric Acid, empty and stir the acid *slowly* into the water. Do *not* pour the water into or upon the acid, else a dangerous explosion may occur. You will see the reason why when performing the dilution in the proper way as directed.

COMMON STOCK OF REAGENTS AND OTHER MATERIALS

(Put up in bottles, jars, and boxes)

For the use of a class of 30 to 40 students.

1 gallon Alcohol (Methylated Spirits), 2 quarts Vinegar; 2 quarts Aqua Ammoniae (Ammonia Water); 1 jar Dry Water - slacked Lime (covered); 1 jar Unslacked Lime (Lime, Quicklime), covered; 2 lbs. Manganese Dioxide (MnO_2); 3 lbs. Chlorate of Potash, crystals; 4 lbs. Commercial Granulated Zinc or Zinc Cuttings; ½ quire Blue and ½ quire Red Litmus Paper, for cutting up small for experiments; 1 oz. Litmus Powder; 1 small jar Hard Charcoal, in small pieces; 1 small jar Soft Charcoal, easily burned; 1 lb. Powdered Sulphur and a little in lumps; ½ oz. Magnesium Wire or Ribbon; 1 lb. Iron Filings; 4 lbs. Soft Glass Tubing, ¼ in. bore, easily softened in lamp flame for bending, to make Delivery Tubes, &c.; 1 Triangular File for cutting glass tubing; 1 Round File; ½ lb. Fine, Flexible Iron Wire (Florists' Wire), in 1 ft. lengths; ½ lb. Brass and 1 lb. Copper Wire, Flexible, ordinary size; 3 dozen good Perforated Rubber Stoppers, with one perforation in each, to fit Test Tubes; a set of ordinary Corks, assorted sizes; 1 lb. Cane Sugar; 5 lbs. Common Salt; 2 lbs. Blue Vitriol; 1 pkt. Aniline Dye (red); 1 lb. Caustic Soda, in sticks; ½ lb. Caustic Potash, in sticks; 60 Splinters of Dry Hardwood, 7 or 8 in. long; Specimens of Common Metals, in strips or in the form of nails or wire; 2 or more cheap Balances, sensitive to about $\frac{1}{10}$ of a gram—the Harvard Trip Balance will answer well. In addition, this Stock Supply should include, at first, the Apparatus and Chemicals needed for making up the Students' Sets given in the preceding list, and for replenishing the sets as needed. The greater part of these supplies will last an average school for several years.